Stochastic Estimation of Nonpoint-Source Return Flows and Pollutant Mass Loading to Two Reaches of the Arkansas River in Colorado

John T. Cox and Timothy K. Gates
Department of Civil and Environmental Engineering, Colorado State University

Abstract. In many irrigated agricultural areas, water quality has become a concern for stakeholders in addition to water quantity. At high concentrations, nutrients, salinity, and trace elements have the potential to impact aquatic life, livestock, crop yields, and human health. In these systems, it is necessary to estimate water and solute mass inflows and outflows to quantify the system mass balance. Moreover, such estimates are valuable in calibrating distributed-parameter models of stream-aquifer systems for use in exploring impacts of alternative interventions on irrigation-influenced flows and mass loading. Many techniques are available to estimate surface water flows and mass fluxes. However, direct measurement of groundwater return flow and mass fluxes along with distributed nonpoint-source surface flows is nearly impossible, and most estimates contain a marked degree of uncertainty. This study presents a stochastic mass balance model utilized to estimate flow and pollutant mass loading of nitrate (NO_3), sulfate (SO_4), total dissolved solids (TDS), selenium (Se), and uranium (U) in groundwater and unaccounted-for surface water returning along two reaches of the Lower Arkansas River in Colorado. The flow component of the mass balance model of the river reaches accounts for gauged tributary inflows, diversion outflows, river channel storage change, direct precipitation, and evapotranspiration. In order to estimate the pollutant component of the mass balance, empirical relationships are developed relating pollutant concentrations to specific conductance and gauged flow rates. Uncertainty in these estimates due to spatiotemporal variability and measurement error is accounted for where possible in the mass balance. Statistical distributions are developed to describe the uncertainty in the empirical concentration relationships, the uncertainty of river channel geometry, lab measurement error, and stream gauging error, among others. The model is employed using Monte Carlo simulation, with output estimates represented as a 95 percent probability interval.